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Sea Floor Sediment Mapping from Multibeam Sonar: SediMap®

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Introduction: NRL's Marine Geosciences Division has developed a capability (SediMap®) to characterize the sediment on the sea floor using the acoustic backscatter information from multibeam bathymetric sonars. Sea floor properties play an important role in mine warfare and antisubmarine warfare, as well as in nonmilitary applications, such as laying communication cables along the ocean floor. Of particular interest is the ability to distinguish between mud, fine sand, coarse sand, and gravel or rock. Ocean-survey operations use multibeam sonars to acquire acoustic data for measuring water depth (bathymetry) worldwide. These sonars also measure acoustic backscatter from many incident angles with respect to the sea floor. Since the angular response of the backscatter largely depends on the type of sediment on the sea floor sediment, this same data also provides a means to classify the ocean bottom.

Multibeam Sonar: The Naval Oceanographic Office (NAVOCEANO) conducts surveys to measure water depth and other ocean properties worldwide using their TAGS-60 survey vessels. The water depth is measured by two sonars, EM 121A and EM 1002, each with more than 100 sound beams aimed at different angles below the ship as shown in Fig. 4. The multibeam sonars emit sound frequencies of 12 kHz and 95 kHz, respectively. Strength of the sonars' echo from a particular spot on the bottom returning in the direction of the sonar is known as the backscattering strength and depends on both the incidence angle of the beam with the sea floor and the acoustic properties of the sediment.

Scattering Model: For the purpose of acoustic scattering, the sea floor is sometimes modeled by treating it as a fluid. The scattering is then a result of the roughness and acoustic impedance (reflectivity) of the water-sediment boundary and interaction with the underlying sediment. The backscatter model used in SediMap® was developed by the Applied Physics Laboratory at the University of Washington (APL-UW)[1] and predicts backscattering strength as a function of

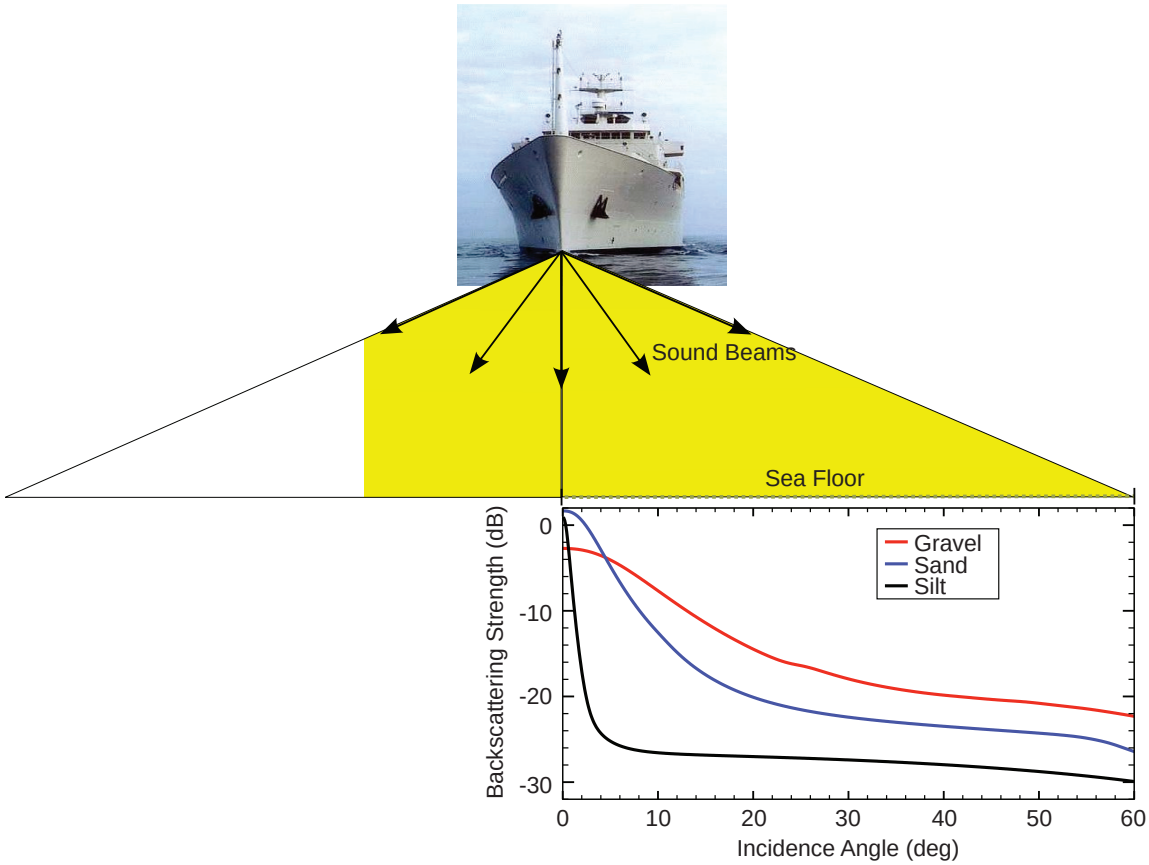

FIGURE 4
(Top) Representation of multibeam sonar from a TAGS-60 survey vessel. (Bottom) Plots showing backscattering strength varying with incidence angle for typical gravel (red), sand (blue), and silt (black).

both the incidence angle and geo-acoustic sea floor properties.

Optimization: SediMap® fits backscattering strength vs incident angle data to the APL-UW scattering model and yields estimates for sediment mean-grain-size.[2] First, a global optimization technique, simulated annealing, is used to find the set of geo-acoustic parameters that best match the backscatter data. Based on empirical correlations in geo-acoustic properties from historical sediment data, these parameters are then associated with a mean-grain-size for the surface sediments.

Naval Survey Testing: Validation tests conducted by NAVOCEANO demonstrate strong correlation with ground truth samples. Testing was performed for water depths ranging from 5 to 500 m with sediment ranging from mud (very fine sediment) to gravel (very coarse sediment). The survey data were available in a number of regions including the Persian Gulf (see Fig. 5), the Gulf of Mexico, and off the coast of Ft. Lauderdale, Florida. In some cases, the ground truth samples were collected during the same survey as the acoustic data. Otherwise, ground truth was obtained from archived data sources. NAVOCEANO is using SediMap® products to improve the Navy's sea floor environmental databases. This new methodology provides a means to rapidly assess and map sea floor sediments using existing bathymetric sensors by simply adding an additional processing step.

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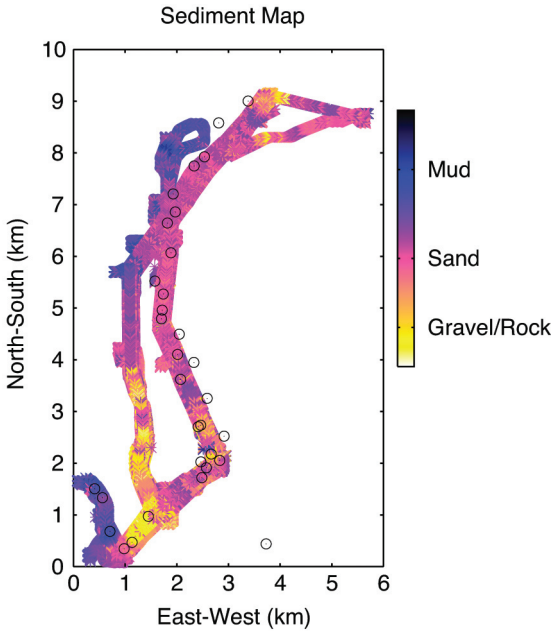

FIGURE 5
SediMap®'s indication of ocean sediments in the Persian Gulf exhibiting strong correlation with the grab samples (in circles). The correlation coefficient is 0.77.

References

[1] Applied Physics Laboratory at the University of Washington, "High-Frequency Ocean Environmental Acoustic Models Handbook," Technical Report APL-UW TR 9407, October 1994, Seattle, Washington.

[2] F.W. Bentrem, J. Sample, M.T. Kalcic, and M.E. Duncan, "High-frequency Acoustic Sediment Classification in Shallow Water," *Proceedings of Oceans 2002 MTS/IEEE Conference and Exhibition*, Biloxi, MS, October 2002, Volume 1, pp. 7-11. ★